

FORM PTO-1390  
(REV. 9-2001)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

KSE 201

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

10/009862

INTERNATIONAL APPLICATION NO.

PCT/DE 00/01839

INTERNATIONAL FILING DATE

6 JUNE 2000

PRIORITY DATE CLAIMED

10 JUNE 1999

TITLE OF INVENTION

APPARATUS FOR NON-CONTACT THREE-DIMENSIONAL MEASURING OF...

APPLICANT(S) FOR DO/EO/US DIETER GEUBAUER; BERNHARD STEIGER; ROSA  
GORZEL; DIETER AUERBACH; ANDRE VECSEI; RALF STRAUER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

## Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☒ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☐ Other items or information:

U.S. APPLICATION NO (if known, see 37 CFR 1.51) <b>10/009862</b>		INTERNATIONAL APPLICATION NO <b>PCT/DE00/01839</b>		ATTORNEY'S DOCKET NUMBER <b>KSE201</b>	
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21. <input checked="" type="checkbox"/> The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1040.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$740.00</b>  International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$710.00</b>  International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b> <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				<b>CALCULATIONS PTO USE ONLY</b>         <div style="border: 1px solid black; padding: 5px; margin: 5px 0;">\$ 890.00</div>	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	23 - 20 =	3	x \$18.00	\$ 54.00	
Independent claims	3 - 3 =		x \$84.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ \$280.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 944.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				+ \$ 472.00	
<b>SUBTOTAL =</b>				\$ 472.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$	
<b>TOTAL FEES ENCLOSED =</b>				\$ 472.00	
				Amount to be refunded:	\$
				charged:	\$

a. ☐ A check in the amount of \$ \_\_\_\_\_ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
 A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
 overpayment to Deposit Account No. 110224. A duplicate copy of this sheet is enclosed.

d. ☒ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card  
 information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

**Horst M. Kasper**  
**13 Forest Drive**  
**Warren, N.J. 07059**

SIGNATURE  
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 NAME  
**28,559**  
 REGISTRATION NUMBER

## THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Dieter Gebauer et al.

Serial No: Art Unit:

Filing Date:

Title: APPARATUS FOR NON-CONTACT THREE-DIMENSIONAL  
MEASURING OF BODIES AND METHOD FOR DETERMINING A  
SYSTEM OF COORDINATES FOR MEASURING POINT  
COORDINATES

PCT No.: PCT/DE00/01839 Filing Date: 6 June 2000

Priority: Country: Germany No.: 199 26 439.2 Filing Date: 10 June 1999

Country: Germany No.: 299 10 132.0 Filing Date: 10 June 1999

December 10, 2001

Attorney's Docket No.: KSE201

**PRELIMINARY AMENDMENT**

Hon. Commissioner of Patents and Trademarks

Box PCT

Washington, D.C. 20231

SIR:

This is a preliminary amendment to provide certain corrections in the above captioned patent application. The applicant petitions that, if required, the time for response be extended and the corresponding fee be charged. The Commissioner is hereby authorized to charge any additional fees, which may be required to Acct. No. 11-0224. The Applicant further respectfully requests that this response be accepted as a bona fide effort to meet any



## CLEAN VERSION OF THE AMENDED CLAIMS

1. An apparatus for non-contact three-dimensional measurement of bodies consisting of a turntable to receive a body and an optical triangulation sensor with at least one radiation source, radiation detector, and an optical system, characterized in that said triangulation sensor (2) is placed above said turntable (1) and is movable along an axis using a driving mechanism so that radiation from the radiation source hits said body, that said body is located on the turntable (1) in a system of coordinates determined, on the one hand, by at least two parallel lines ( $g_1$ ,  $g_2$ ) or body edges with a known spacing ( $d$ ) and angles ( $\alpha$ ,  $\beta$ ) of the turntable (1) and, on the other hand, by at least two measuring points at known distances ( $R_1$ ,  $R_2$ ) from a center ( $M$ ) and known displacement ( $c$ ) of the triangulation sensor (2) between these measuring points, and that said turntable (1), the driving mechanism and said triangulation sensor (2) are connected to a data processing and control unit.

2. The apparatus according to claim 1, characterized in that said radiation source (3) of said triangulation sensor (2) is placed in such a way that the

radiation from the radiation source (3) impinges perpendicular to the surface of said turntable (1).

3. The apparatus according to claim 1, characterized in that said triangulation sensor (2) is placed on a hinge or ball-and-socket joint above said turntable (1) and is movable along an axis using the driving mechanism, and that there is at least one sensor that directly and/or indirectly measures the angle between the radiation (9) and the workpiece.

9. A method for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies comprising

- a turntable (1) to receive said body,
- an optical triangulation sensor (2) with at least one radiation source (3), radiation detector (4), and an optical system that is placed above said turntable (1) and is movable along an axis using a driving mechanism so that the radiation (9) from said radiation source (3) hits said body, and

- a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2), wherein at least two lines (g1, g2) or body edges running in parallel at a known distance (d) are used to determine angles ( $\alpha$ ,  $\beta$ ) of turntable (1) by rotating said lines and subsequently capturing them in the measuring spot of said triangulation sensor (2) in a first and a second position of said triangulation sensor (2) displaced from said first position by the known dislocation c, said angles being used to calculate the distances R1, R2 of said triangulation sensor (2) from the center (M) of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to the turntable center (M) as coordinates of origin.

11. The method according to claim 9, characterized in that the parallel lines or body edges of a measuring body are arranged straightly or annularly on said turntable (1).

12. The method according to claim 9, characterized in that a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

13. An apparatus for non-contact three-dimensional measurement of bodies comprising

a turntable to receive a body;

a radiation source;

a radiation detector;

a driving mechanism;

a data processing and control unit;

an optical system,

wherein the radiation source, the radiation detector, and the optical system form an optical triangulation sensor; wherein the triangulation sensor (2) is disposed above said turntable (1) and is movable along an axis using the driving mechanism so that radiation from the radiation source hits said body, wherein said body is located on the turntable (1) in a system of coordinates determined, on the one hand, by at least two parallel lines ( $g_1$ ,  $g_2$ ) or body edges with a known spacing ( $d$ ) and angles ( $\alpha$ ,  $\beta$ ) of the turntable (1) and, on the other hand, by at least two measuring points at known distances ( $R_1$ ,  $R_2$ ) from a center ( $M$ ) and known displacement ( $c$ ) of the triangulation sensor (2)



between these measuring points, and that said turntable (1), and wherein the driving mechanism and said triangulation sensor (2) are connected to the data processing and control unit.

14. The apparatus according to claim 13, wherein said radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) impinges perpendicular to the surface of said turntable (1).

15. The apparatus according to claim 13 further comprising a hinge or ball-and-socket joint disposed above said turntable (1), wherein said triangulation sensor (2) is placed on the hinge or ball-and-socket joint above said turntable (1) and is movable along an axis using the driving mechanism; and at least one sensor measuring an angle between the radiation (9) and a workpiece.

16. The apparatus according to claim 13 further comprising

a covering body of known thickness and with low-scattering surfaces, wherein the body is a body producing excessive scattering in the form of multiple reflections of the radiation (9) from said radiation source (3), wherein at least some areas of the surface of the body which produces excessive scattering in the form of multiple reflections of the radiation (9) from said radiation source (3) are fixedly and/or removably covered by the covering body of known thickness and with low-scattering surfaces.

17. The apparatus according to claim 13, wherein the parallel lines or body edges of a measuring body are straight or annular on said turntable (1).

18. The apparatus according to claim 13, wherein a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

19. The apparatus according to claim 13, further comprising at least two stops for bodies disposed at said turntable (1), wherein the at least two end stops for bodies are placed at a distance from each other.

20. The apparatus according to claim 13, further comprising  
at least one magnet integrated into said turntable (1).

21. A method for determining a system of coordinates for measuring points  
on an apparatus for non-contact three-dimensional measuring of bodies  
comprising  
installing a turntable;  
receiving a body on the turntable;  
placing an optical triangulation sensor (2) including at least one radiation  
source (3), radiation detector (4), and an optical system above said turntable  
(1);  
moving the triangulation sensor (2) with a driving mechanism along an axis  
so that the radiation (9) from said radiation source (3) hits said body, and  
using at least two lines (g1, g2) or body edges running in parallel at a known  
distance (d) to determine angles ( $\alpha$ ,  $\beta$ ) of turntable (1) by rotating said lines  
and subsequently capturing them in the measuring spot of said triangulation  
sensor (2) in a first and a second position of said triangulation sensor (2)

displaced from said first position by the known dislocation  $c$  in a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2); and

using said angles to calculate the distances  $R_1$ ,  $R_2$  of said triangulation sensor (2) from a center (M) of said turntable and to further calculate the coordinates  $x$ ,  $y$  of said triangulation sensor (2) relative to a turntable center (M) as coordinates of origin in the data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2).

22. The method according to claim 21, further comprising placing said radiation source (3) of said triangulation sensor (2) in such a way that the radiation from the radiation source (3) is perpendicular to the surface of said turntable (1).

23. The method according to claim 21, further comprising placing a measuring body with at least two edges or a measuring body with at least two lines on said turntable (1) only during a determining of a system of coordinates.

## MARKED-UP VERSION OF THE AMENDED CLAIMS

*(Version with markings to show changes made)*

1. (amended) An apparatus for non-contact three-dimensional measurement of bodies consisting of a turntable to receive [the] a body and an optical triangulation sensor with at least one radiation source, radiation detector, and an optical system, characterized in that said triangulation sensor (2) is placed above said turntable (1) and [can be moved] is movable along an axis using a driving mechanism so that radiation from the radiation source hits said body, that said body is located on the turntable (1) in a system of coordinates determined, on the one hand, by at least two parallel lines (g1, g2) or body edges with a known spacing (d) and angles ( $\alpha$ ,  $\beta$ ) of the turntable (1) and, on the other hand, by at least two measuring points at known distances (R1, R2) from [the] a center (M) and known displacement (c) of the triangulation sensor (2) between these measuring points, and that said turntable (1), the driving mechanism and said triangulation sensor (2) are connected to a data processing and control unit.

2. (amended) The apparatus according to claim 1, characterized in that said radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) [is] impinges perpendicular to the surface of said turntable (1).

3. (amended) The apparatus according to claim 1, characterized in that said triangulation sensor (2) is placed on a hinge or ball-and-socket joint above said turntable (1) and [can be moved] is movable along an axis using the driving mechanism, and that there is at least one sensor that directly and/or indirectly measures the angle between the radiation (9) and the workpiece.

9. (amended) A method for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies comprising

- a turntable (1) to receive said body,

- an optical triangulation sensor (2) with at least one radiation source (3), radiation detector (4), and an optical system that is placed above said turntable (1) and [can be moved] is movable along an axis using a driving mechanism so that the radiation (9) from said radiation source (3) hits said body, and

- a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2), wherein at least two lines (g1, g2) or body edges running in parallel at a known distance (d) are used to determine angles ( $\alpha$ ,  $\beta$ ) of turntable (1) by rotating said lines and subsequently capturing them in the measuring spot of said triangulation sensor (2) in a first and a second position of said triangulation sensor (2) displaced from said first position by the known dislocation c, said angles being used to calculate the distances R1, R2 of said triangulation sensor (2) from the center (M) of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to the turntable center (M) as coordinates of origin.

11. (amended) The method according to [claims] claim 9 [or 10], characterized in that the parallel lines or body edges of a measuring body are arranged straightly or annularly on said turntable (1).

12. (amended) The method according to [any one of claims] claim 9 [through 11], characterized in that a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

13. (new) An apparatus for non-contact three-dimensional measurement of bodies comprising

a turntable to receive a body;

a radiation source;

a radiation detector;

a driving mechanism;

a data processing and control unit;

an optical system,



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wherein the radiation source, the radiation detector, and the optical system form an optical triangulation sensor; wherein the triangulation sensor (2) is disposed above said turntable (1) and is movable along an axis using the driving mechanism so that radiation from the radiation source hits said body, wherein said body is located on the turntable (1) in a system of coordinates determined, on the one hand, by at least two parallel lines ( $g_1$ ,  $g_2$ ) or body edges with a known spacing ( $d$ ) and angles ( $\alpha$ ,  $\beta$ ) of the turntable (1) and, on the other hand, by at least two measuring points at known distances ( $R_1$ ,  $R_2$ ) from a center ( $M$ ) and known displacement ( $c$ ) of the triangulation sensor (2) between these measuring points, and that said turntable (1), and wherein the driving mechanism and said triangulation sensor (2) are connected to the data processing and control unit.

14. (new) The apparatus according to claim 13, wherein said radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) impinges perpendicular to the surface of said turntable (1).

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15. (new) The apparatus according to claim 13, further comprising a hinge or ball-and-socket joint disposed above said turntable (1), wherein said triangulation sensor (2) is placed on the hinge or ball-and-socket joint above said turntable (1) and is movable along an axis using the driving mechanism; and at least one sensor measuring an angle between the radiation (9) and a workpiece.

16. (new) The apparatus according to claim 13, further comprising a covering body of known thickness and with low-scattering surfaces, wherein the body is a body producing excessive scattering in the form of multiple reflections of the radiation (9) from said radiation source (3), wherein at least some areas of the surface of the body which produces excessive scattering in the form of multiple reflections of the radiation (9) from said radiation source (3) are fixedly and/or removably covered by the covering body of known thickness and with low-scattering surfaces.

17. (new) The apparatus according to claim 13, wherein the parallel lines or body edges of a measuring body are straight or annular on said turntable (1).

18. (new) The apparatus according to claim 13, wherein a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

19. (new) The apparatus according to claim 13, further comprising at least two stops for bodies disposed at said turntable (1), wherein the at least two end stops for bodies are placed at a distance from each other.

20. (new) The apparatus according to claim 13, further comprising at least one magnet integrated into said turntable (1).

21. (new) A method for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies comprising  
installing a turntable;

receiving a body on the turntable;

placing an optical triangulation sensor (2) including at least one radiation source (3), radiation detector (4), and an optical system above said turntable (1);

moving the triangulation sensor (2) with a driving mechanism along an axis so that the radiation (9) from said radiation source (3) hits said body, and using at least two lines (g1, g2) or body edges running in parallel at a known distance (d) to determine angles ( $\alpha$ ,  $\beta$ ) of turntable (1) by rotating said lines and subsequently capturing them in the measuring spot of said triangulation sensor (2) in a first and a second position of said triangulation sensor (2) displaced from said first position by the known dislocation c in a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2); and

using said angles to calculate the distances R1, R2 of said triangulation sensor (2) from a center (M) of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to a turntable center (M) as coordinates of origin in the data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2).



**REMARKS**

Claims 1 through 12 continue to be in the case.

Claims 1, 9, 11, 12 are being amended.

New claims 13 through 23 are being submitted.

The new claims are based as follows:

Claim:	Basis:
13	claim 1
14	claim 2
15	claim 3
16	claim 4
17	claim 5
18	claim 6
19	claim 7
20	claim 8
21	claim 9
22	claim 10
23	claim 12

The present preliminary amendment is submitted in order to improve claim language and to eliminate multiple dependencies between claims.

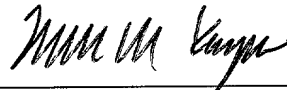
Should be there any multiple dependent claims remaining, such remaining multiple dependent claims are to be deemed as treated as canceled by the applicant.

Entry of the above-recited corrections prior to calculation of the fee is respectfully requested.

Respectfully submitted,

Dieter Gebauer et al.

By:



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Tel.: (908)526-1717; Reg. No. 28559  
Attorney's Docket No.: KSE201

\*%PAMEND(KSE201A1(December 10, 2001(rep

Description

2/pts

Apparatus for non-contact three-dimensional measuring of bodies and method for determining a system of coordinates for measuring point coordinates

This invention relates to apparatuses for non-contact three-dimensional measurement of bodies according to the introductory part of claim 1 and methods for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies according to the introductory part of claim 9.

The triangulation method is one of the most common methods used in range and length measurement and two- or three-dimensional contour detection. A triangulation sensor is used, and the beam from a laser diode is focused through a lens on the workpiece. It produces a bright light spot. When this light spot is viewed at a fixed angle using a position detector or camera, the place where the spot is shown moves within the image as soon as the intersecting point of the laser beam and the workpiece are moved relative to the sensor. This displacement is measured to determine the distance of the workpiece or its surface contour when moving perpendicular to the illuminating laser beam.

DE 43 01 538 A1 (Apparatus and arrangement for non-contact three-dimensional measuring, in particular for measuring plaster casts of teeth) uses a turntable on which the body to be measured is placed, a triangulation sensor and a data processing and control unit connected to it to determine the geometry of rounded parts. Measurement is based on either

- local calibration of each measuring head that must take into account in summary the actual position of measuring surfaces in space by coordinate transformation, or

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- calibration of the entire measuring system using at least one calibrating body where all points in space that are of interest are entered into a joint calibration table. Calibration cannot be avoided.

DE 44 07 518 A1 describes an apparatus and a method for non-contact measurement of three-dimensional objects based on optical triangulation. The triangulation sensor can be moved in one direction (y direction) and pivoted in the x plane across a preset angular position at a fixed point that can be chosen. This involves two independent movements of the triangulation sensor. The object to be measured is located on the turntable. This turntable on the one hand provides rotary movement, on the other hand it can be moved in vertical direction to the movement of the sensor using another driving mechanism. The movements of the triangulation sensor and the turntable determine the coordinates of the measuring spot of the radiation source. Tilting the triangulation sensor allows measuring most dimensions of undercuts, covered points, pocket holes and similar spots of the object. DE 40 37 383 A1 (Method for continuous contactless measurement of outlines and arrangement for carrying out the measuring procedure) uses triangulation to determine the outer contour line of a moving profile. The sensor only detects the distance to the profile and thus its contour. The measuring spot cannot be placed in a system of coordinates.

DE 195 04 126 A1 (Apparatus and method for contactless measurement of three-dimensional objects using optical triangulation), DE 197 27 226 A1 (Set-up of measuring instruments and method for contactless measurement of the three-dimensional spatial shape of a groove in a spectacles frame), and US 5 270 560 (Method and apparatus for measuring workpiece surface topography) record the outlines of workpieces or workpiece parts to be detected step by step. The respective workpiece or workpiece part is only measured relatively.

Coordinate measurement on an object surface is carried out in DE 40 26 942 A1 (Method for contactless measurement of object surfaces) where images are recorded using a camera. This camera is mounted to an index arm of a coordinate gauging device that can be moved in three spatial directions (x and y directions and pivoting). The object to be measured is located on a turntable.

The problem of the invention described in claims 1 and 9 is to provide easy three-dimensional measurement of the geometry of a body and to easily and correctly match triangulation measurement data with the three-dimensional geography of a body.

This problem is solved by the characteristics listed in claims 1 and 9.

The apparatus for non-contact three-dimensional measurement of bodies and the method for determining a system of measuring point coordinates on an apparatus for non-contact three-dimensional measurement of bodies are characterized by particular simplicity and easy implementation. Advantageously, this makes the apparatus and method applicable in production sites for special workpieces. The design is very simple, and the method requires simple and cost-efficient set-up, which ensures a wide range of uses.

The basis of the system is an optical triangulation sensor. The beam of a laser diode is focused through a lens on the workpiece. A light spot emerges on the workpiece. This spot is recorded at a fixed angle by a radiation detector. When the workpiece moves relative to the triangulation sensor, the place where the spot is shown also moves within the image. The

outline of the workpiece is determined by measuring this displacement.

Before the workpieces are measured, a system of coordinates for three-dimensional matching of the workpiece geometry is determined in a first measurement. A body with known dimensions of its edges or lines is placed on the turntable and measured during one rotation using the triangulation sensor. The body can be placed on the turntable in any position. Instead of said body, lines can be placed onto or into the surface of the turntable.

The triangulation sensor can scan the workpiece by moving the sensor along just one axis and rotating of the workpiece. Controlled triggering of the respective driving mechanisms and use of the system of coordinates results in continuous detection of the workpiece geometry at a high measuring data rate and precision. The apparatus according to the invention is thus characterized by its minimal design. The low number of movements required, i.e. one translatory movement of the triangulation sensor and a rotational movement of the turntable, results in determining the outline of a body with a minimal error of measurement.

Advantageously, the apparatus is particularly suited for measuring rotationally symmetric workpieces. Advantageously, the method can be used to measure rotationally symmetric workpieces.

Control and calculation of workpiece geometry is advantageously controlled using a computer.

Preferred embodiments of the invention are described in claims 2 to 8 and 10 to 12.

The surface profile of the workpiece is detected by one perpendicular movement to the illuminating laser beam of the triangulation sensor according to the improvement described in claim 2.

The angle of radiation incidence from the triangulation sensor can be changed using a hinge or ball-and-socket joint according to the improvement described in claim 3. Elevations or recesses in the workpiece surface that might not be found can thus be detected or spotted easier. The coordinate data of the incident radiation can be determined by measuring the angle of the triangulation sensor.

Image distortions on the detector that result in errors of measurement may occur when bodies are measured whose surfaces scatter the radiation from the radiation source by causing multiple reflections. To prevent these errors as much as possible, at least the areas of interest of a body to be measured are covered according to the improvement described in claim 4 with bodies of known thickness whose surfaces are low-scattering with regard to the radiation used. The thickness of these covering bodies is subtracted from the measured value when evaluating the results of measurement so that the original dimension of the body is a corrected measured value.

Favorable variants for determining the system of coordinates for the workpieces according to the improvement described in claim 5 are parallel lines or body edges the distance of which is known. Accordingly designed bodies or bodies comprising such lines are placed on the turntable.

The system of coordinates has to be measured for commissioning and after a change of location only. Thus the bodies for determining the system of coordinates according to the improvement described in claim 6 are required for these measures only.

According to the improvements described in claims 7 and 8, at least two end stops placed at a distance from each other or a magnet incorporated in the turntable are preferred variants of guided workpiece positioning. These positioning aids also largely prevent position changes of the workpieces on the turntable when the turntable is moving. If workpieces are similar in shape, these positioning aids ensure that approximately the same position is retained when changing workpieces. This results in simplified and faster geometry measurement. Thus production monitoring systems can respond faster to any incorrect changes of the manufacturing process.

The illuminating laser beam of the triangulation sensor may be vertically directed towards the turntable surface according to the improvement described in claim 10.

According to the improvement described in claim 11, it is also preferred when determining the system of coordinates for measuring points to use straight or annular lines as parallel lines or body edges.

The system of coordinates has to be measured for commissioning and after a change of location only. Thus the bodies for determining the system of coordinates according to the improvement described in claim 12 are required for these measures only.

An embodiment of the invention will be explained with reference to Figs. 1 to 4. Wherein:

Fig. 1 shows a schematic view of an apparatus for non-contact three-dimensional measurement of bodies,

Fig. 2 is a schematic view of an apparatus with two lines running in parallel and at a known spacing on the turntable,

Fig. 3 and

Fig. 4 show the determination of a system of coordinates using two parallel lines or body edges with a known distance from each other, known angles, and a known dislocation of the triangulation sensor.

An apparatus for non-contact three-dimensional measuring of bodies and a method for determining a system of coordinates for measuring points will be explained in greater detail with reference to an embodiment below.

The apparatus for non-contact three-dimensional measurement of bodies consists of a turntable 1 to place the body on and an optical triangulation sensor 2 with at least one radiation source 3, a radiation detector 4, and optical equipment such as a focusing lens 5 and a projection lens 6.

The radiation source 3 is a laser diode, and the radiation detector 4 is a monolithic image sensor.

A U-shaped frame 8 is mounted on a base plate 7. The turntable 1 is placed on the base plate 7 and centered to the center section of the U-shaped frame 8 (see Fig. 1). The diameter of turntable 1 is smaller than the length of the center section of the U-shaped frame 8.

The center section of the U-shaped frame 8 further comprises a guidance into which the triangulation sensor 2 is placed correspondingly. The triangulation sensor 2 can thus be moved across the turntable 1 using a suitable driving mechanism. The driving mechanism is integrated into the center section. The triangulation sensor 2 is placed onto the center section so that the radiation 9 from the radiation source 3 is perpendicular to the turntable 1.

The center of the turntable 1 is determined; it marks the point of origin in a system of polar coordinates.

This system of coordinates is created for the bodies to be measured during first commissioning and when changing the position of the apparatus.

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The turntable 1 comprises several parallel lines (Figs. 2 and 3), or a measuring body is placed on the turntable 1 to determine the system of coordinates. This measuring body comprises either straight parallel edges or lines for determining a system of coordinates (similar to those shown in Figs. 2 and 3). These lines or body edges may be placed anywhere on the turntable. The spacing between these straight lines or body edges is known. The turntable makes one full turn while the system of coordinates is determined. During this process, lines g1 and g2 are captured in the measuring spots C and D of the triangulation sensor 2. At the same time, the angles of the measuring spots that coincide with line g1 or line g2 are measured. Trigonometric calculations involving the known distance  $d = AB$  between the parallel lines or body edges g1 and g2, the measured angles  $\alpha$  and  $\beta$  and the right angle between the straight line MB and the lines g1 and g2 result in the radius R1 and thus the distance between the triangulation sensor 2 and the center of the turntable 1 (shown in Fig. 3).

$$R1 = \frac{d}{\cos \beta/2 - \cos \alpha/2}$$

The distance R2 is determined in the same way as R1 by a displacement c of the triangulation sensor 2 or the turntable 1, and a second rotation of the turntable and measurement of angles  $\alpha$  and  $\beta$  (shown in Fig. 4). The direction of the displacement c also defines one direction of the system of coordinates. The coordinates x and y of the system of coordinates are determined using the Pythagorean theorem. In this way, the distance of the center of the turntable 1 from the current position of the triangulation sensor 2 x and y+c are obtained. Now the measuring points of the body can be dimensioned.

$$Y = \frac{R_2^2 - R_1^2 - c^2}{2 \cdot c}$$

$$X = \sqrt{R_1^2 - \left( \frac{R_2^2 - R_1^2 - c^2}{2 \cdot c} \right)^2}$$

The measurement can be supported by several circles with different radii that are placed on the turntable 1. These make it easier to allocate dimensions and to position the body on the turntable 1.

The measuring body can be designed as a film with several annular lines. It may remain on the turntable 1 as an adjustment device for the bodies. The film is therefore glued to the top of the turntable 1.

The driving mechanisms of the turntable 1 and the triangulation sensor 2 are connected to a computer that controls them. This computer is also used for evaluating the results of measurement. This is why the radiation source 3 and the radiation detector 4 of the triangulation sensor 2 are connected to the computer, too.

Bodies to cover measuring areas of interest can be used if a body to be measured produces scattering such as multiple reflections of the radiation 9 from the radiation source 3. These covering bodies have a known thickness and consist of a material that does not allow excessive multiple reflections. Such covering bodies may consist of ceramics, for example. This allows basically error-free measurement of surface contours even of bodies that have shining surfaces.



In another embodiment, the U-shaped frame 8 is L-shaped and placed in such a way that one of its limbs runs in parallel to, and on top of, the turntable 1. This limb is the guidance for the triangulation sensor 2 (shown in Fig. 2).

We claim:

1. An apparatus for non-contact three-dimensional measurement of bodies consisting of a turntable to receive the body and an optical triangulation sensor with at least one radiation source, radiation detector, and an optical system, characterized in that said triangulation sensor (2) is placed above said turntable (1) and can be moved along an axis using a driving mechanism so that radiation from the radiation source hits said body, that said body is located on the turntable (1) in a system of coordinates determined, on the one hand, by at least two parallel lines ( $g_1$ ,  $g_2$ ) or body edges with a known spacing ( $d$ ) and angles ( $\alpha$ ,  $\beta$ ) of the turntable (1) and, on the other hand, by at least two measuring points at known distances ( $R_1$ ,  $R_2$ ) from the center ( $M$ ) and known displacement ( $c$ ) of the triangulation sensor (2) between these measuring points, and that said turntable (1), the driving mechanism and said triangulation sensor (2) are connected to a data processing and control unit.

2. The apparatus according to claim 1, characterized in that said radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) is perpendicular to the surface of said turntable (1).

3. The apparatus according to claim 1, characterized in that said triangulation sensor (2) is placed on a hinge or ball-and-socket joint above said turntable (1) and can be moved along an axis using the driving mechanism, and that there is at least one sensor that directly and/or indirectly measures the angle between the radiation (9) and the workpiece.

4. The apparatus according to claim 1, characterized in that at least some areas of the surface of a body that produces excessive scattering in the form of multiple reflections of the radiation (9) from said radiation source (3) are fixedly and/or removably covered by a covering body of known thickness and with low-scattering surfaces.

5. The apparatus according to claim 1, characterized in that the parallel lines or body edges of a measuring body are straight or annular on said turntable (1).

6. The apparatus according to claim 1, characterized in that a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

7. The apparatus according to claim 1, characterized in that said turntable (1) has at least two end stops for bodies placed at a distance from each other.

8. The apparatus according to claim 1, characterized in that at least one magnet is integrated into said turntable (1).

9. A method for determining a system of coordinates for measuring points on an apparatus for non-contact three-dimensional measuring of bodies comprising

- a turntable (1) to receive said body,
- an optical triangulation sensor (2) with at least one radiation source (3), radiation detector (4), and an optical system that is placed above said turntable (1) and can be moved

along an axis using a driving mechanism so that the radiation (9) from said radiation source (3) hits said body, and  
- a data processing and control unit for turntable (1), driving mechanism and triangulation sensor (2), wherein at least two lines (g1, g2) or body edges running in parallel at a known distance (d) are used to determine angles ( $\alpha$ ,  $\beta$ ) of turntable (1) by rotating said lines and subsequently capturing them in the measuring spot of said triangulation sensor (2) in a first and a second position of said triangulation sensor (2) displaced from said first position by the known dislocation c, said angles being used to calculate the distances R1, R2 of said triangulation sensor (2) from the center (M) of said turntable and to further calculate the coordinates x, y of said triangulation sensor (2) relative to the turntable center (M) as coordinates of origin.

10. The method according to claim 9, characterized in that said radiation source (3) of said triangulation sensor (2) is placed in such a way that the radiation from the radiation source (3) is perpendicular to the surface of said turntable (1).

11. The method according to claims 9 or 10, characterized in that the parallel lines or body edges of a measuring body are arranged straightly or annularly on said turntable (1).

12. The method according to any one of claims 9 through 11, characterized in that a measuring body with at least two edges or a measuring body with at least two lines is placed on said turntable (1) when determining a system of coordinates only.

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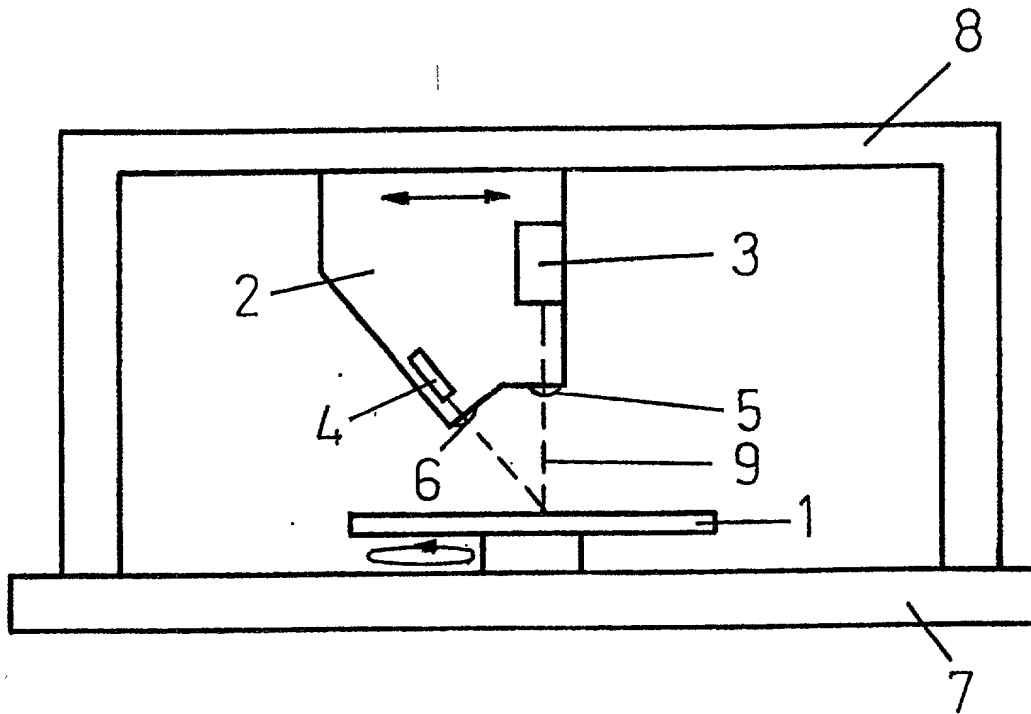


Fig. 1

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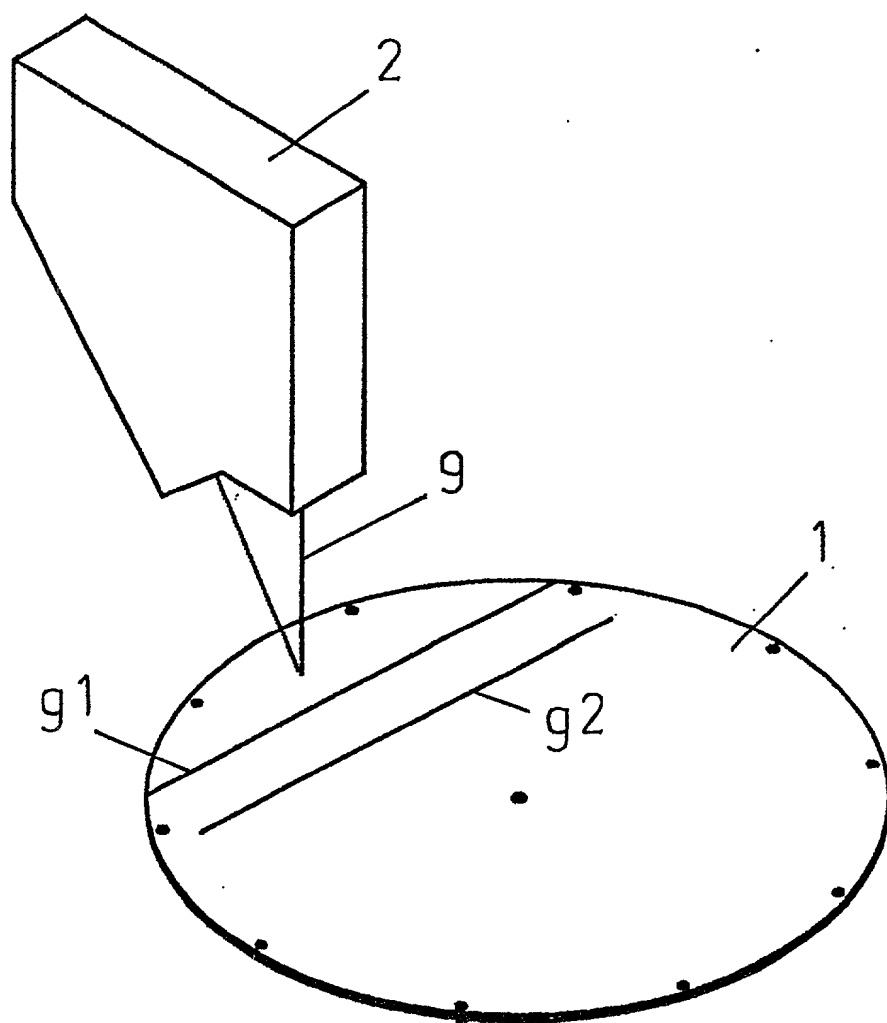


Fig. 2

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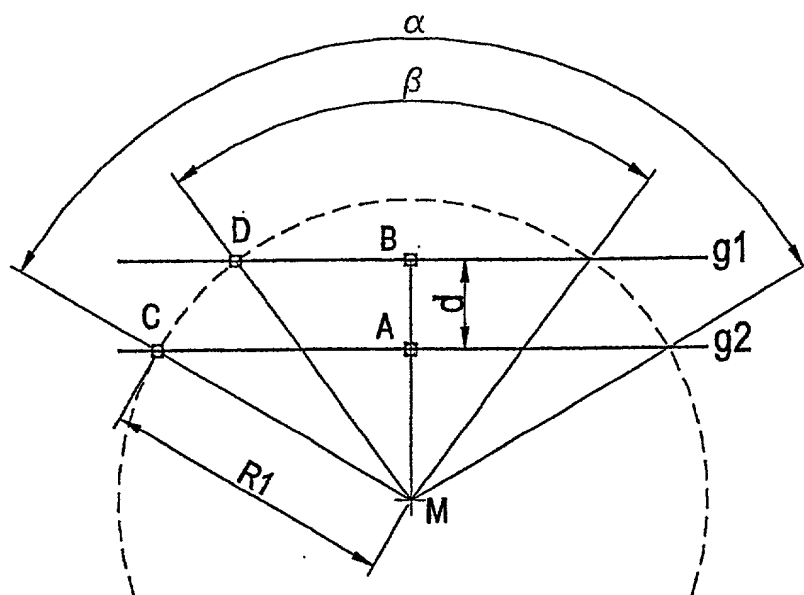


Fig. 3

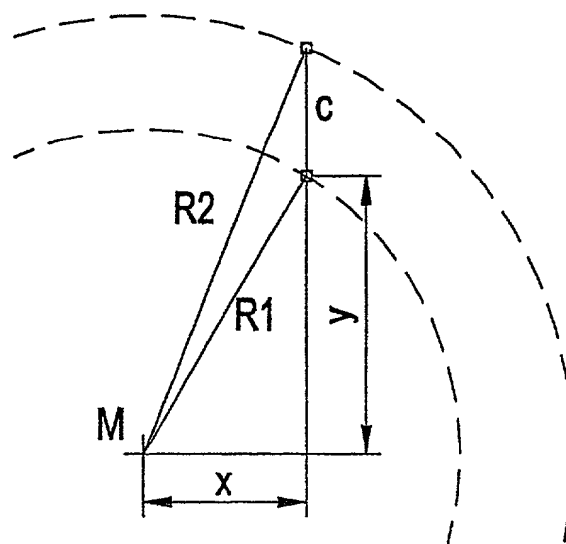


Fig. 4

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Dieter Gebauer

Serial No: Art Unit:

Filing Date:

Title: APPARATUS FOR NON-CONTACT THREE-DIMENSIONAL  
MEASURING OF BODIES AND METHOD FOR DETERMINING  
A SYSTEM OF COORDINATES FOR MEASURING POINT  
COORDINATES

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION  
Erklärung Für Patentanmeldungen Mit Vollmacht  
German Language Declaration Kse201

Als nachstehend benannter Erfinder erkläre ich hiermit an  
Eidesstatt:

As a below named inventor, I hereby declare that:

daß mein Wohnsitz, meine Postanschrift und meine Staats-  
angehörigkeit den im Nachstehenden nach meinem Namen aufgeführten  
Angaben entsprechen,

My residence, post office address and citizenship are as stated  
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daß ich, nach bestem Wissen der ursprüngliche, erste und  
alleinige Erfinder (falls nachstehend nur ein Name angegeben ist)  
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nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin,  
für den dieser Antrag gestellt wird und für den ein Patent  
beantragt wird für die Erfindung mit dem Titel:

Vorrichtung zur berührungslosen dreidimensionalen Vermessung von  
Körpern und Verfahren zur Bestimmung eines Koordinatensystems für  
Messpunktkoordinaten

I believe I am the original, first and sole inventor (if only one  
name is listed below) or an original, first and joint inventor  
(if plural names are listed below) of the subject matter which is  
claimed and for which a patent is sought on the invention  
entitled:

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**APPARATUS FOR NON-CONTACT THREE-DIMENSIONAL MEASURING OF BODIES  
AND METHOD FOR DETERMINING A SYSTEM OF COORDINATES FOR MEASURING  
POINT COORDINATES**

deren Beschreibung (nur eines der nachfolgenden Kästchen  
ankreuzen)

the specification of which (check only one item below)

< > hier beigefügt ist.  
is attached hereto.

< > am \_\_\_\_\_ als U.S.-Anmeldung, Seriennummer  
eingereicht wurde und am \_\_\_\_\_ abgeändert wurde (falls  
tatsächlich abgeändert).  
was filed as US Application Serial No. \_\_\_\_\_ on  
and was amended on \_\_\_\_\_ (if applicable).

<X> am 6. Juni 2000 als internationale PCT-Anmeldung, Nummer  
PCT/DE00/01839 eingereicht wurde und am \_\_\_\_\_ unter  
PCT-Artikel 36 abgeändert wurde (falls tatsächlich abgeändert).  
was filed as PCT international application, Number PCT/DE00/01839  
on 6 June 2000 and was amended under PCT Article 36  
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Ich bestätige hiermit, daß ich den Inhalt der obigen  
Patentanmeldung einschließlich der Ansprüche durchgesehen und  
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I hereby state that I have reviewed and understand the contents  
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I acknowledge the duty to disclose information which is material  
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Ich beanspruche hiermit ausländische Prioritätsvorteile gemäß  
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Country (if PCT, indicate PCT) Land (falls PCT, PCT angeben)	Application No. Anmeldungsnummer	Date of Filing (day, month, year) Anmeldedatum (Tag, Monat, Jahr)	Priority Claimed under 35 USC 119 Priorität unter 35 USC 119 beansprucht
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Germany	199 26 439.2	10 June 1999	<X>Yes < >No Ja Nein
Germany	299 10 132.0	10 June 1999	

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U.S. APPLICATIONS		STATUS (Check one)
U.S. Application No.	U.S Filing Date	Patented Pending Abandoned
AMERIKANISCHE ANMELDUNGEN		STAND (ein Kästchen ankreuzen)
Seriennummer	Anmeldedatum	Patentiert Anhängig Aufgegeben

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**PCT APPLICATIONS DESIGNATING THE U.S.**

PCT Application Number	PCT Filing Date	U.S.Ser.Nos. assigned (if any)
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DIE USA BENENNENDE PCT-ANMELDUNGEN		
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**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)

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Ich erkläre hiermit, daß alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und daß ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, daß wissentlich und vorsätzlich falsche Angaben gemäß Paragraph 1001, Absatz 18 der Zivilprozeßordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden können, und daß derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patenten gefährden können.

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 Full name of sole or first inventor:

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Unterschrift des Erfinders  
 Inventor's signature

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PTO 1391 (10-83)  
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	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2
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